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Der Präsident des Europäischen Patentamts;
Im Auftrag

For the President of the European Patent Office

Le Président de l'Office européen des brevets
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Substrate carrier and method for making a substrate carrier

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Substrate carrier and method for making a substrate carrier**FIELD OF THE INVENTION**

The present invention relates to a substrate carrier for carrying a lithographic substrate, comprising a first member provided with an open hollow structure that is open to at least one side of said member. The invention further relates to a method for making such a substrate carrier, and a lithographic projection apparatus comprising such a substrate carrier, said apparatus comprising:

- a radiation system for providing a projection beam of radiation;
- a support structure for supporting patterning means, the patterning means serving to pattern the projection beam according to a desired pattern; and
- a projection system for projecting the patterned beam onto a target portion of the substrate.

15 PRIOR ART

The term "patterning means" as here employed should be broadly interpreted as referring to means that can be used to endow an incoming radiation beam with a patterned cross-section, corresponding to a pattern that is to be created in a target portion of the substrate; the term "light valve" can also be used in this context.

Generally, the said pattern will correspond to a particular functional layer in a device being created in the target portion, such as an integrated circuit or other device (see below). Examples of such patterning means include:

- A mask. The concept of a mask is well known in lithography, and it includes mask types such as binary, alternating phase-shift, and attenuated phase-shift, as well as various hybrid mask types. Placement of such a mask in the radiation beam causes selective transmission (in the case of a transmissive mask) or reflection (in the case of a reflective mask) of the radiation impinging on the mask, according to the pattern on the mask. In the case of a mask, the support structure will generally be a mask table, which ensures that the mask can be held at a desired position in the incoming radiation beam, and that it can be moved relative to the beam if so desired;
- A programmable mirror array. One example of such a device is a matrix-addressable surface having a viscoelastic control layer and a reflective surface. The basic principle behind such an apparatus is that (for example) addressed areas of the

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reflective surface reflect incident light as diffracted light, whereas unaddressed areas reflect incident light as undiffracted light. Using an appropriate filter, the said undiffracted light can be filtered out of the reflected beam, leaving only the diffracted light behind; in this manner, the beam becomes patterned according to the addressing pattern of the matrix-addressable surface. An alternative embodiment of a programmable mirror array employs a matrix arrangement of tiny mirrors, each of which can be individually tilted about an axis by applying a suitable localized electric field, or by employing piezoelectric actuation means. Once again, the mirrors are matrix-addressable, such that addressed mirrors will reflect an incoming radiation beam in a different direction to unaddressed mirrors; in this manner, the reflected beam is patterned according to the addressing pattern of the matrix-addressable mirrors. The required matrix addressing can be performed using suitable electronic means. In both of the situations described hereabove, the patterning means can comprise one or more programmable mirror arrays. More information on mirror arrays as here referred to can be gleaned, for example, from United States Patents US 5,296,891 and US 5,523,193, and PCT patent applications WO 98/38597 and WO 98/33096, which are incorporated herein by reference. In the case of a programmable mirror array, the said support structure may be embodied as a frame or table, for example, which may be fixed or movable as required; and

20 - A programmable LCD array. An example of such a construction is given in United States Patent US 5,229,872, which is incorporated herein by reference. As above, the support structure in this case may be embodied as a frame or table, for example, which may be fixed or movable as required. For purposes of simplicity, the rest of this text may, at certain locations, specifically direct itself to examples involving a mask and mask table; however, the general principles discussed in such instances should be seen in the broader context of the patterning means as hereabove set forth.

25 Lithographic projection apparatus can be used, for example, in the manufacture of integrated circuits (ICs). In such a case, the patterning means may generate a circuit pattern corresponding to an individual layer of the IC, and this pattern can be imaged onto a target portion (e.g. comprising one or more dies) on a substrate (silicon wafer) that has been coated with a layer of radiation-sensitive material (resist). In general, a single wafer will contain a whole network of adjacent target portions that

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are successively irradiated via the projection system, one at a time. In current apparatus, employing patterning by a mask on a mask table, a distinction can be made between two different types of machine. In one type of lithographic projection apparatus, each target portion is irradiated by exposing the entire mask pattern onto the

5 target portion in one go; such an apparatus is commonly referred to as a wafer stepper or step-and-repeat apparatus. In an alternative apparatus — commonly referred to as a step-and-scan apparatus — each target portion is irradiated by progressively scanning the mask pattern under the projection beam in a given reference direction (the "scanning" direction) while synchronously scanning the substrate table parallel or

10 anti-parallel to this direction; since, in general, the projection system will have a magnification factor M (generally < 1), the speed V at which the substrate table is scanned will be a factor M times that at which the mask table is scanned. More information with regard to lithographic devices as here described can be gleaned, for example, from US 6,046,792, incorporated herein by reference.

15 In a manufacturing process using a lithographic projection apparatus, a pattern (e.g. in a mask) is imaged onto a substrate that is at least partially covered by a layer of radiation-sensitive material (resist). Prior to this imaging step, the substrate may undergo various procedures, such as priming, resist coating and a soft bake. After exposure, the substrate may be subjected to other procedures, such as a post-exposure bake (PEB), development, a hard bake and measurement/inspection of the imaged features. This array of procedures is used as a basis to pattern an individual layer of a device, e.g. an IC. Such a patterned layer may then undergo various processes such as etching, ion-implantation (doping), metallization, oxidation, chemo-mechanical polishing, etc., all intended to finish off an individual layer. If several layers are

20 required, then the whole procedure, or a variant thereof, will have to be repeated for each new layer. Eventually, an array of devices will be present on the substrate (wafer). These devices are then separated from one another by a technique such as dicing or sawing, whence the individual devices can be mounted on a carrier, connected to pins, etc. Further information regarding such processes can be obtained, for example, from

25 the book "Microchip Fabrication: A Practical Guide to Semiconductor Processing", Third Edition, by Peter van Zant, McGraw Hill Publishing Co., 1997, ISBN 0-07-067250-4, incorporated herein by reference.

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For the sake of simplicity, the projection system may hereinafter be referred to as the "lens"; however, this term should be broadly interpreted as encompassing various types of projection system, including refractive optics, reflective optics, and catadioptric systems, for example. The radiation system may also include components 5 operating according to any of these design types for directing, shaping or controlling the projection beam of radiation, and such components may also be referred to below, collectively or singularly, as a "lens". Further, the lithographic apparatus may be of a type having two or more substrate tables (and/or two or more mask tables). In such 10 "multiple stage" devices the additional tables may be used in parallel, or preparatory steps may be carried out on one or more tables while one or more other tables are being used for exposures. Dual stage lithographic apparatus are described, for example, in US 5,969,441 and WO 98/40791, both incorporated herein by reference.

In the lithographic apparatus the substrate and the patterning means have to be positioned fast and accurately with respect to the projection system. The substrate 15 table and the supporting structure, referred to as the substrate carrier, should be made of a material which:

- is stiff to reduce the risks of vibrations,
- is lightweight so that it can be easily accelerated.

Present day substrate carriers are often manufactured from a solid block of 20 a material having a very low coefficient of thermal expansion and which are therefore thermally stable. In order to reduce the moving mass of the substrate carrier so that the substrate carrier can be positioned more accurately, despite of possible fluctuations in the temperature, known substrate carriers are for the above reasons often made of glass or another ceramic material, machined, e.g. by milling, to form open spaces inside said 25 solid block.

The substrate carrier may have a box-like structure with a first side provided with a space for receiving the substrate. By machining the substrate carrier to reduce its weight, a maximum reduction of weight of about 65% can be achieved.

Even bigger reductions in weight are preferred to further improve the possible 30 handling speed and positional accuracy of the substrate carrier.

However if even more material is removed from the known substrate carrier, this will reduce the stiffness of the substrate carrier in an unacceptable manner and as a result of that, the dynamic properties of the substrate carrier will become less optimal.

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Furthermore the substrate carrier will become more sensitive to unwanted disturbances, such as vibrations, that reduce the accuracy by which the substrate carrier can be positioned. A problem with the milling cut procedure is that it is difficult to make thin walled structures consequently of low weight because the accuracy of the milling cut machine is largely dependent on the depth it reaches in the material of the substrate carrier. Also stability due to the side forces of the milling technique plays a role. Thin walls will not be stable enough to withstand the side forces.

It is an object of the present invention to provide a substrate carrier which has an even further reduced weight without compromising the stiffness and dynamical properties thereof.

SUMMARY OF THE INVENTION

This object is achieved according to the invention by the substrate carrier as specified in the opening paragraph, characterized in that said substrate carrier further comprises a second member connected to the first member, such that a closed hollow internal structure is formed between said members.

The inventors have discovered that a substantially closed hollow box provides a substrate carrier that can be lighter than known substrate carriers having at least one open third side to allow for the removal of material. A substrate carrier that is substantially closed, i.e. that has no open side, will be stiffer than a substrate carrier having an open side, as will be understood by a person skilled in the art. Consequently, the walls of such a substrate carrier can be made thinner, to obtain a certain required degree of stiffness compared to conventional substrate carriers. This is a result of the production process of such a lightweight substrate carrier. The substrate carrier may contain relatively small openings, for instance, for guiding wiring to the inside of the carrier. The inside of the carrier could contain positioning devices or measuring devices, that need cabling. Therefore, it will be understood that the term substantially closed, also comprises substrate carrier having such smaller openings, that do not effect the rigidity of the total substrate carrier.

According to an embodiment of the present invention, the second member has an open, hollow structure which together with the open hollow structure of the first member forms the closed internal structure of the substrate carrier. Providing both members with an open, hollow structure, simplifies forming a closed internal structure.

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According to an embodiment of the present invention, in the open, hollow structure a plurality of spaced apart ribs are provided. These ribs make the substrate carrier more rigid, adding minimal weight.

According to an embodiment of the present invention, a third member is 5 provided, positioned between the first and second member, which third member has an open, hollow structure, that is open to two opposite sides thereof. Positioning a third member between the first and second members is an easy way to increase the height of the substrate carrier, while the thickness of the first and second member remain relatively small, enabling accurate manufacturing processes, such as milling, and thus 10 creating relatively thin walls.

According to an embodiment of the present invention, the third member comprises a plurality of spaced apart ribs in said open, hollow structure. This provides extra stiffness to the third member.

According to an embodiment of the present invention, an additional plate is 15 positioned against the ribs. This is an easy way to make the substrate carrier more rigid, and providing a single level interface for machinery placed inside the substrate carrier.

According to an embodiment of the present invention, different members of the substrate carrier are made of different materials, of which at least one is chosen from glass, carbon or other ceramics. The substrate holder can be made out of the same 20 material (monolithic) so that the physical properties are exactly the same. However, it can also be advantageous to make different parts of the substrate holder from different materials in order to obtain different characteristics on different places in the substrate holder.

According to a further aspect, the invention relates to a lithographic 25 projection apparatus comprising:

- a radiation system for providing a projection beam of radiation;
- a support structure for supporting patterning means, the patterning means serving to pattern the projection beam according to a desired pattern; and
- a projection system for projecting the patterned beam onto a target portion 30 of the substrate, characterized in, that said apparatus comprises a substrate table for holding a substrate, comprising a substrate carrier according to the invention. A substrate carrier according to the invention can advantageously be used in a

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lithographic projection apparatus, since fast and accurate positioning of substrate carrier is required in such apparatus.

According to an other aspect, the present invention relates to a method for making a substrate carrier, for carrying a lithographic substrate, comprising

5 - connecting at least two members to each other to form a substrate carrier, where the members are formed in such a way that the substrate carrier comprises a substantially closed, hollow internal structure. Forming a substrate carrier with a substantial closed, hollow internal structure, give a substrate carrier, that is relatively rigid and light-weighted.

10 According to an embodiment of the present invention, the method comprises

- forming the at least two members by means of a milling technique.

15 Since the members of which the substrate carrier is formed are less thick than the substrate carrier, the milling process can be applied with an increased accuracy, creating thinner walls. Thinner wall structures have also become possible, because of the fact that water jet cutting techniques, that have no side forces, can be used for certain members.

20 The depth in which material is taken from the substrate carrier determines the accuracy of the machining, in particular the milling cut procedure. If the substrate carrier is made out of one part the total height of the substrate carrier will determine the depth over which the material has to be removed with the milling cut procedure. By making the substrate carrier out of two pieces the depth in which both parts have to be subjected to the milling cut procedure is reduced and the accuracy with which both parts can be manufactured is increased and the wall thickness of the walls can be 25 reduced, making the substrate carrier even lighter.

According to an embodiment of the present invention, the method further comprises providing at least one of the members with means for holding a substrate. Substrates, such as used in the lithographic projection industry, need to be positioned fast and accurately, so substrate carriers according to the invention can advantageously 30 be used in this field of technology. Such a substrate holder can hold a substrate in a fixed and well-defined position.

According to an embodiment of the present invention, the method comprises forming the substrate carrier, that is provided with a mirror on at least one

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side of the substrate carrier, arranged to be used in combination with position determining unit, e.g. interferometric measuring means. Such a mirror can be used in cooperation with a interferometric measuring device, allowing fast and accurate positional measurement.

5 According to an embodiment of the present invention, the method comprises

- forming a hollow structure in a third member in such a way that the third member comprises a first and a second open side,
- attaching the first member (15) to the first open side of the third member

10 (16) and attaching the second member (17) to the second open side of the third member (16) in such a way that the substrate carrier (10) comprises a substantially closed, hollow internal structure. This allows producing a substrate carrier being relatively thick.

According to an embodiment of the present invention, the method

15 comprises

- forming a hollow structure in the first and second member in such a way that the first and second member have one open side,
- attaching the open side of the first member to the first open side of the third member and attaching the open side of the second member to the second open side of

20 the third member in such a way that the substrate holder comprises a substantially closed, hollow internal structure. By dividing the substrate carrier in more than two members, the members that are not the top or bottom member can be formed using techniques other than milling techniques, such as water jet cutting techniques, that are more accurate and work independent of the height of the member. Water jet cutting

25 machines work as a saw and can make holes with two open sides. The preciseness of the machine is very high and therefore the walls can be made very small independent of the height of the third part. Further on, milling techniques can be applied to the top and bottom member even more accurate, since the thickness of those parts can be made relatively thin.

30 According to an embodiment of the present invention, the method comprises

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- providing an additional plate in between the first and third member and/or the second and third member. This provides a relatively light weight strengthening to the substrate carrier.

According to an embodiment of the present invention, the method
5 comprises

- forming a hollow structure in the third member using an extrusion technique or a water jet cutting technique. These techniques are known to be very accurate and can therefore create thin walls inside the second member, forming the hollow structure. These techniques are also advantageous since no forces that are
10 directed sideways occur.

According to an embodiment of the present invention, the method
comprises

- forming holes in the substrate carrier. Such holes can be used to adapt the inner structure of the substrate carrier to fluctuations in the pressure. The holes can also
15 be used to supply control or power cables to machinery inside the substrate carrier.

Although specific reference may be made in this text to the use of the apparatus according to the invention in the manufacture of ICs, it should be explicitly understood that such an apparatus has many other possible applications. For example, it may be employed in the manufacture of integrated optical systems, guidance and
20 detection patterns for magnetic domain memories, liquid-crystal display panels, thin-film magnetic heads, etc. The skilled artisan will appreciate that, in the context of such alternative applications, any use of the terms "reticle", "wafer" or "die" in this text should be considered as being replaced by the more general terms "mask", "substrate" and "target portion", respectively.

25 In the present document, the terms "radiation" and "beam" are used to encompass all types of electromagnetic radiation, including ultraviolet (UV) radiation (e.g. with a wavelength of 365, 248, 193, 157 or 126 nm) and extreme ultra-violet (EUV) radiation (e.g. having a wavelength in the range 5-20 nm), as well as particle beams, such as ion beams or electron beams.

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BRIEF DESCRIPTION OF THE INVENTION

Embodiments of the invention will now be described, by way of example only, with reference to the accompanying schematic drawings in which corresponding reference symbols indicate corresponding parts, and in which:

5 - Figure 1 schematically depicts a lithographic projection apparatus according to an embodiment of the invention;

- Figure 2 schematically depicts a substrate carrier according to the prior art;

- Figure 3 schematically depicts a substrate carrier according to a first embodiment of the present invention;

10 - Figure 4a and 4b depict a substrate carrier according to a further embodiment of the present invention;

- Figure 5a and 5b depict alternative embodiments of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

15 Figure 1 schematically depicts a lithographic projection apparatus 1 according to a particular embodiment of the invention. The apparatus comprises:

- a radiation system Ex, IL, for supplying a projection beam PB of radiation (e.g. ultra violet radiation). In this particular case, the radiation system also comprises a radiation source LA;

20 - a first object table (mask table) MT provided with a mask holder for holding a mask MA (e.g. a reticle), and connected to first positioning means PM for accurately positioning the mask with respect to item PL;

- a second object table (substrate table) WT provided with a substrate holder for holding a substrate W (e.g. a resist-coated silicon wafer), and connected to second positioning means PW for accurately positioning the substrate with respect to item PL;

25 and

- a projection system ("lens") PL (e.g. lenses, mirrors) for imaging an irradiated portion of the mask MA onto a target portion C (e.g. comprising one or more dies) of the substrate W.

30 As here depicted, the apparatus is of a reflective type (i.e. has a reflective mask). However, in general, it may also be of a transmissive type, for example (with a transmissive mask). Alternatively, the apparatus may employ another kind of patterning means, such as a programmable mirror array of a type as referred to above.

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The source LA produces a beam of radiation. This beam is fed into an illumination system (illuminator) IL, either directly or after having traversed conditioning means, such as a beam expander Ex, for example. The illuminator IL may comprise adjusting means AM for setting the outer and/or inner radial extent

5 (commonly referred to as σ -outer and σ -inner, respectively) of the intensity distribution in the beam. In addition, it will generally comprise various other components, such as an integrator IN and a condenser CO. In this way, the beam PB impinging on the mask MA has a desired uniformity and intensity distribution in its cross-section.

It should be noted with regard to figure 1 that the source LA may be within 10 the housing of the lithographic projection apparatus (as is often the case when the source LA is a mercury lamp, for example), but that it may also be remote from the lithographic projection apparatus, the radiation beam which it produces being led into the apparatus (e.g. with the aid of suitable directing mirrors); this latter scenario is often the case when the source LA is an excimer laser. The current invention and claims 15 encompass both of these scenarios.

The beam PB subsequently intercepts the mask MA, which is held on a mask table MT. Having traversed the mask MA, the beam PB passes through the lens PL, which focuses the beam PB onto a target portion C of the substrate W. With the aid of the second positioning means PW (and interferometric measuring means IF), the 20 substrate table WT can be moved accurately, e.g. so as to position different target portions C in the path of the beam PB. Similarly, the first positioning means PM can be used to accurately position the mask MA with respect to the path of the beam PB, e.g. after mechanical retrieval of the mask MA from a mask library, or during a scan. In 25 general, movement of the object tables MT, WT will be realized with the aid of a long-stroke module (coarse positioning) and a short-stroke module (fine positioning), which are not explicitly depicted in figure 1. However, in the case of a wafer stepper (as opposed to a step-and-scan apparatus) the mask table MT may just be connected to a short stroke actuator, or may be fixed. Mask MA and substrate W may be aligned using mask alignment marks M1, M2 and substrate alignment marks P1, P2.

30 The depicted apparatus can be used in two different modes:

1. In step mode, the mask table MT is kept essentially stationary, and an entire mask image is projected in one go (i.e. a single "flash") onto a target portion C. The substrate table WT is then shifted in the x and/or y directions so that a different target portion C

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can be irradiated by the beam PB; and

2. In scan mode, essentially the same scenario applies, except that a given target portion C is not exposed in a single "flash". Instead, the mask table MT is movable in a given direction (the so-called "scan direction", e.g. the y direction) with a speed v , so

5 that the projection beam PB is caused to scan over a mask image; concurrently, the substrate table WT is simultaneously moved in the same or opposite direction at a speed $V = Mv$, in which M is the magnification of the lens PL (typically, $M = 1/4$ or $1/5$). In this manner, a relatively large target portion C can be exposed, without having to compromise on resolution.

10 In a substrate carrier 9 according to the prior art and as depicted in Fig. 2, at least one side of the substrate carrier 9 is open and used to create a hollow structure in the substrate carrier 9, for instance, with a milling process. The hollow structure is formed in order to reduce the weight of the substrate carrier 9. In the interior of the substrate carrier 9 ribs 8 of different heights are formed to provide a multilevel

15 interface for machinery, such as motors and sensors, that needs to be placed in the substrate carrier 9. This resulted in an substrate carrier 9 having at least one open side. On top of the substrate carrier 9 a substrate, such as patterning means or a wafer can be positioned. Therefore, the substrate carrier is preferably provided with devices to fix the substrate on its position.

20 In the substrate carrier 10 according to a first embodiment of the invention, as depicted by a schematic side view in Figure 3, the substrate carrier 10 is divided in a top and a bottom member 11, 12. Although the top and bottom members 11, 12 are shown here as being separated, the members are connected to each other to form a substrate carrier 10. Different techniques for connecting will be described below.

25 The members 11, 12 are made hollow by using, for instance, a milling process, but since the thickness of the top and bottom member 11 and 12 is smaller than that of the complete substrate carrier 10, the milling process can be performed more accurately. As a result of this, the walls that remain after the milling process can be thinner. This provides a substrate carrier 10 that is relatively light weight.

30 By splitting the substrate carrier 10 in a top and a bottom member 11, 12 halfway its height, the depth is reduced by a factor 2, compared to a substrate carrier 9 with an open box structure. The technique is preferably used for a relatively low substrate carrier 10, of, for instance, less than 80 mm. The two separate members 11,

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12 subsequently have an height of less than 40 mm and the walls of the top 11 and bottom member 12 can have a thickness of approximately 2 - 3 mm. The preferred thickness of the walls depends on the specific requirements. In general, the walls are preferably kept as thin and light weight as possible, however, the substrate carrier 10 should also be rigid and strong enough to allow accurate positioning of the substrate.

5 Since the substrate carrier 10 has a (partially) closed box structure, i.e. it does not have an open side, the structure is much more rigid than known substrate carriers 9 having an open side. Therefore, a minimum amount of material (and mass) is needed to obtain a substrate carrier 10 having an optimal dynamic performance.

10 Fig. 4a shows a three dimensional view of a substrate carrier 10 according to a further embodiment, comprising a top member 11 and a bottom member 12. As can be seen, interior ribs 13, 14 are formed on the inside of the substrate carrier 10, the ribs 13, 14 having different heights. Low ribs 14 are formed to optimise the local stiffness of the substrate carrier 10 and to provide an interface relative to which machinery can be positioned. The machinery can be a plurality of motor and sensors. High ribs 13 are formed to strengthen the main structure of the substrate carrier 10. A more detailed view of the ribs 13, 14 is provided by Fig. 4b. Although Fig. 4a and 4b only show ribs 13, 14 being formed in the bottom member 12, similar ribs 13, 14 are preferably provided in the interior of the top member 11.

20 Of course, also other rib structures could be provided in the top member 11, and bottom member 12. The rib structure shown here has good dynamic properties since the ribs 13, 14 are formed in a triangular structure. It is also possible to form a rib structure in which all the ribs have a similar height or to provide a rib structure in which ribs have a higher diversity of heights, to further improve the properties of the 25 substrate carrier 10.

Fig. 5a shows an alternative embodiment of the substrate carrier 10 according to the present invention. In this embodiment, the substrate carrier 10 is divided in a first member 15, a second member 17 and a third member 16. The first member 15 and second member 17 preferably have a low height, so that a rib structure 30 can be formed with an even higher accuracy. The first member 15 and second member 17 preferably have a height of 2 mm, with ribs 18 formed on it, that extend approximately 10 mm from the surface of the first member 15 and second member 17. The ribs 18 can be formed by a milling process and may have a similar triangular

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structure as discussed above. Of course, the first member 15 and the second member 17 can also be a simple plate and do not need to be a low milled structure with ribs.

The first member 15 and second member 17 can be further strengthened by placing an additional plate 19 on the rib structure, as is shown in Fig. 5b. Such an 5 additional plate 19 is positioned between the first member 15 and the third member 16, and/or between the second member 17 and the third member 16. Plate 19 also provides an accurate single level interface for machinery that needs to be placed inside the substrate carrier 10.

The substrate carrier 10 can be made out of one, two, three, four or even 10 more members.

In a preferred embodiment, the different members of the substrate carrier 10 are dimensioned in such a way, that all the machinery can be placed against the top member 15 of the substrate carrier 10. Therefore the top member 15 including the ribs 18, has to have a thickness that matches with the preferred position of the machinery.

15 In an alternative embodiment, the third member 16 could be split in different sections. This could be done to give the substrate carrier 10 extra stiffness or could be useful if different interface levels need to be provided for the machinery.

The third member 16 is preferably a hollow box with two open sides. The 20 third member 16 can therefore be formed using, for instance, a water jet cutting technique or an extrusion technique. These techniques are very accurate and result in relatively thin interior walls 18 provided in the interior of the third member 16. The interior walls 18 can have a thickness of approximately 1 mm and extend over the full height of the third member 16. In the embodiment shown in Fig. 5a and 5b, the interior walls 18 are formed in a triangular structure for reasons that will readily be understood 25 by a person skilled in the art. Of course, also other structures and thicknesses can be used.

The material the substrate carrier 10 is made of, needs to meet strict 30 mechanical and thermal requirements. In order to minimise the weight of the substrate carrier 10, it is preferably made of a material that has a low density. The density of the material is preferably below 3000 kg/m^3 , for instance 2200 kg/m^3 . However, the material should also provide a stable substrate carrier 10. Therefore, the elastic modulus E of the material is preferably smaller than $10 \times 10^{11} \text{ N/m}^2$, for instance, $0,9 \times 10^{11} \text{ N/m}^2$.

The thermal requirements specifically apply to a low coefficient of thermal expansion and a relatively low value for the heat capacity and the thermal conductivity. Preferably a material is chosen that has a coefficient of thermal conductivity of less than 5×10^{-6} 1/K, for instance even 50×10^{-9} 1/K. The value of the heat capacity is 5 preferably below the 1000 J/(kg K), for instance, 700 J/(kg K). Finally, the heat conductivity is preferably below the 10 W/(m K), for instance 1,3 W/(m K).

In case the lithographic apparatus uses extreme ultra-violet (EUV) radiation (e.g. having a wavelength in the range 5-20 nm), the substrate carrier 10 having the substrate W thereon will be located in a (very) high vacuum environment.

10 When illuminated by EUV radiation, the reflectivity of multi-layer mirrors in the lithographic apparatus degrades due to chemical processes known as oxidation and carbonisation. The contaminating species responsible for these undesirable effects are water vapour and hydrocarbons which are evolved due to the outgassing of all materials in a vacuum environment. Therefore no materials may be used that have unacceptably 15 high vacuum outgassing rates.

Materials such as glass, carbon or other ceramics, such as, for instance, Zerodur (produced by Schott), ULE (Corning), CO210 (Kyocera) have proven to fulfil the above requirements and the substrate carrier 10 is therefore preferably made of these materials. Other examples are HSC701 [Al/SiC] (M³), SiC [direct sintered], SSC-20 802 [Si/SiC] (M³) or GrAS501 [fibre reinforced AL-Si](M³) and the like. When dealing with (very) high vacuum using ceramic low thermal expansion materials will result in a substrate carrier having the appropriate outgassing properties. Furthermore, it will be easier to reach the required vacuum levels in those parts of the lithographic apparatus where such levels are required and the design is insensitive to thermal 25 variations.

It will be readily understood by a person skilled in the art that the substrate carrier 10 can be made of one material (monolithic), but the substrate carrier 10 can also be made of different materials (non-monolithic). This can for instance be done 30 when different characteristics are needed for different parts of the substrate carrier 10.

In the above described embodiments, the substrate carrier 10 is formed by different members. Therefore, the different members need to be attached to each other. This attaching can be achieved in different ways, for instance, by using glue, screws or

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other clamping techniques. Other suitable attaching techniques are, depending on the materials used: ringing, soldering, fusion bonding, frit bonding, firing (co-firing), low temperature glass bonding (Schott technology) or anodic bonding. These techniques are known to a person skilled in the art.

5 The substrate carrier 10 is preferably a closed structure in order to provide optimal dynamic characteristics. However, since the interior space of the substrate carrier 10 can be filled with all kinds of machinery, the substrate carrier 10 can have holes (not shown). These holes in the substrate carrier 10 can be used as venting holes, for instance, for creating a vacuum state inside the hollow structure of the substrate
10 carrier 10, but the holes can also be used for providing energy or control cables to the machinery.

Whilst specific embodiments of the invention have been described above, it will be appreciated that the invention may be practised otherwise than as described. The description is not intended to limit the invention.

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CLAIMS

1. Substrate carrier (10) for carrying a lithographic substrate (W, MA), comprising a first member (11, 15) provided with an open hollow structure that is open to at least one side of said member (10), characterized in that said substrate carrier (10) further comprises a second member (12, 17) connected to the first member (11, 15), such that a closed hollow internal structure is formed between said members (11, 15; 12, 17).
5
- 10 2. Substrate carrier (10) according to claim 1, wherein the second member (12, 17) has an open, hollow structure which together with the open hollow structure of the first member (11, 15) forms the closed internal structure of the substrate carrier (10).
- 15 3. Substrate carrier (10) according to claim 2, wherein in said open, hollow structure a plurality of spaced apart ribs (13, 14) are provided.
4. Substrate carrier (10) according to any of the preceding claims, wherein a third member (16) is provided, positioned between the first and second member (11, 15; 12, 17), which third member (16) has an open, hollow structure, that is open to two opposite sides thereof.
20
5. Substrate carrier (10) according to claim 5, wherein the third member (16) comprises a plurality of spaced apart interior walls (18) in said open, hollow structure.
25
6. Substrate carrier (10) according to claim 3-5, wherein an additional plate (19) is positioned against the ribs (13, 14).
7. Substrate carrier (10) according to any of the preceding claims, where
30 different members of the substrate carrier (10) are made of different materials, of which at least one is chosen from glass, carbon or other ceramics.
8. Lithographic projection apparatus comprising:

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- a radiation system for providing a projection beam of radiation;
- a support structure for supporting patterning means, the patterning means serving to pattern the projection beam according to a desired pattern; and

5 - a projection system for projecting the patterned beam onto a target portion of the substrate, characterized in, that said apparatus comprises a substrate table for holding a substrate, comprising a substrate carrier according to one of the claims 1 – 7.

9. Method for making a substrate carrier (10), for carrying a lithographic substrate (W, MA), comprising

10 - connecting at least two members (11, 12; 15, 17) to each other to form a substrate carrier (10), where the members (11, 12; 15, 17) are formed in such a way that the substrate carrier (10) comprises a substantially closed, hollow internal structure.

15 10. Method according to claim 9, comprising

 - forming the at least two members (11, 12, 15, 17) by means of a milling technique.

11. Method according to claim 9 - 10, further comprising

20 - providing at least one of the members (11, 12, 15, 16, 17) with means for holding a substrate (W, MA).

12. Method according to any of the claims 9 - 11, comprising

25 - forming the substrate carrier (10), that is provided with a mirror on at least one side of the substrate carrier (10), arranged to be used in combination with position determining unit, e.g. interferometric measuring means (IF).

13. Method according to any of the claims 9 ~ 11, comprising

30 - forming a hollow structure in a third member (16) in such a way that the third member (16) comprises a first and a second open side,
 - attaching the first member (15) to the first open side of the third member (16) and attaching the second member (17) to the second open side of the third member

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(16) in such a way that the substrate carrier (10) comprises a substantially closed, hollow internal structure.

14. Method according to claim 13, comprising
 - 5 - forming a hollow structure in the first and the second member (15, 17) in such a way that the first and second member (15, 17) have one open side,
 - attaching the open side of the first member (15) to the first open side of the third member (16) and attaching the open side of the second member (17) to the second open side of the third member (16) in such a way that the substrate holder (10)
 - 10 comprises a substantially closed, hollow internal structure.
15. Method according to any of the claims 9 - 14, comprising
 - providing an additional plate (19) in between the first and third member (15, 16) and/or the second and third member (17, 16).
16. Method according to any of the claims 9 - 15, comprising
 - forming the hollow structure in the third member (16) using an extrusion technique or a water jet cutting technique.
20. 17. Method according to any of the claims 9 - 16, comprising
 - forming holes in the substrate carrier (10).

*Abstract***Substrate carrier and method for making a substrate carrier**

The invention relates to a substrate carrier (10) for carrying a lithographic substrate (W, MA). The substrate carrier (10) comprises a first member (11, 15) provided with an open hollow structure that is open to at least one side of said member (10). The substrate carrier (10) further comprises a second member (12, 17) connected to the first member (11, 15), such that a closed hollow internal structure is formed between said carrier members (11, 15; 12, 17).

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[Fig. 4a]

Fig 1

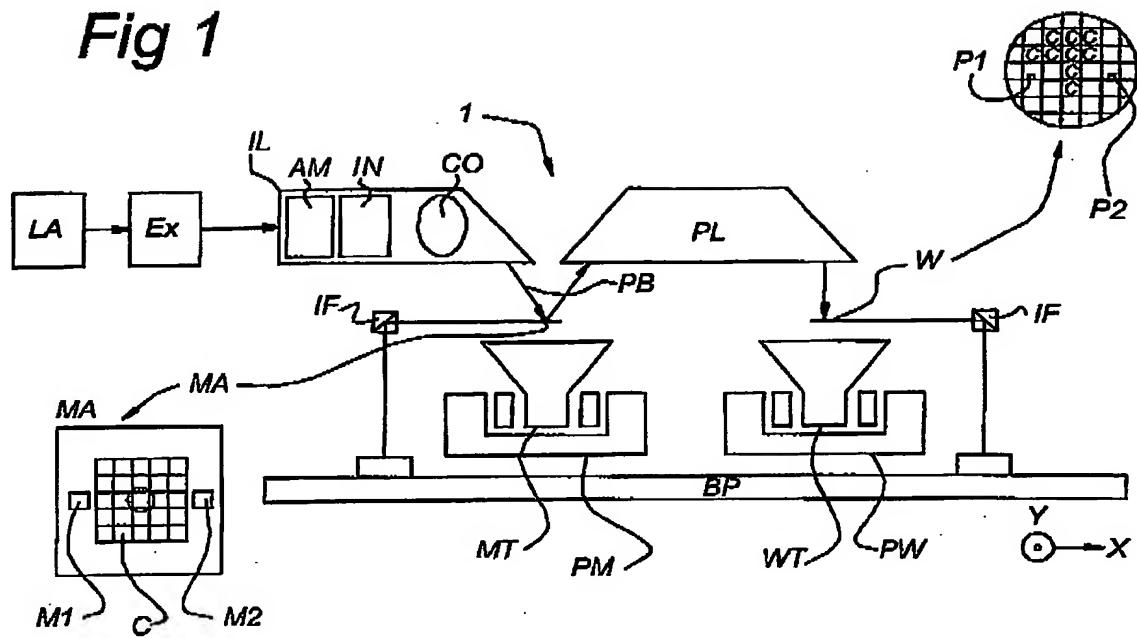


Fig 2

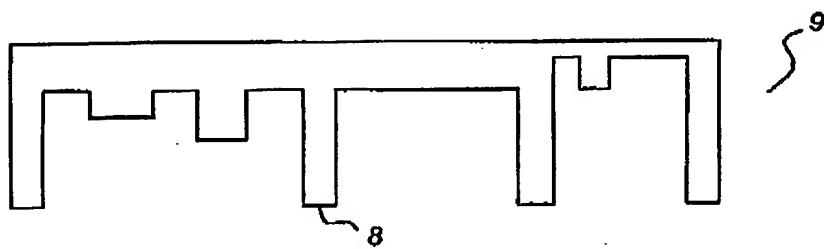


Fig 3

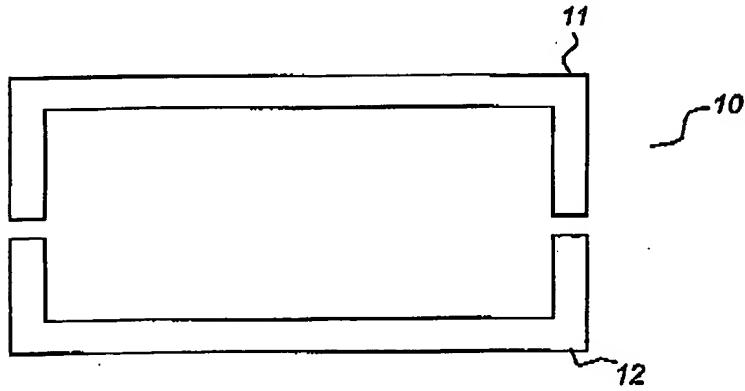


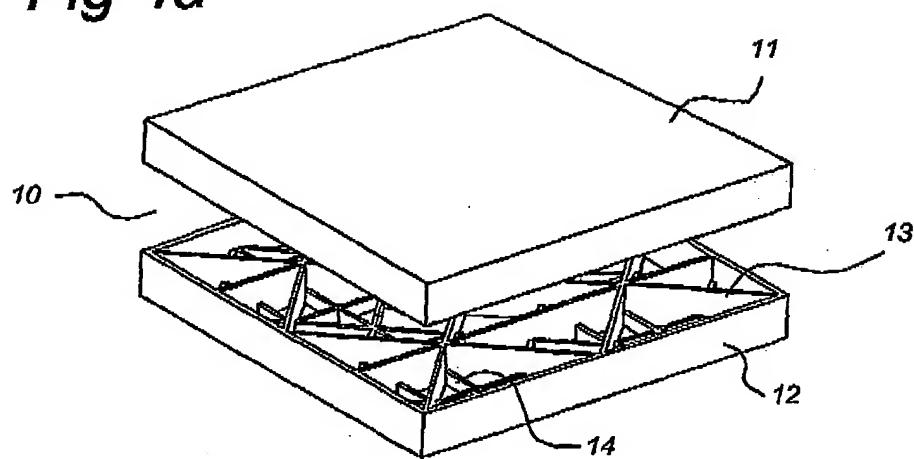
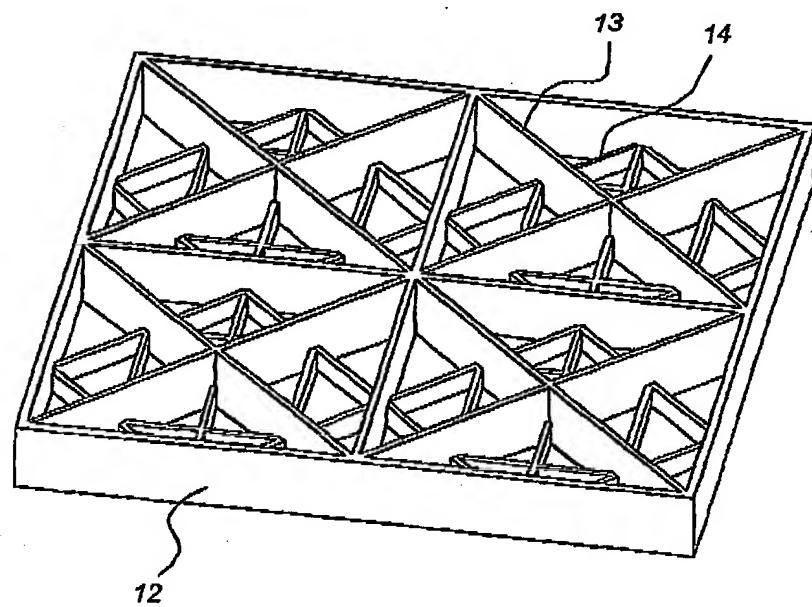
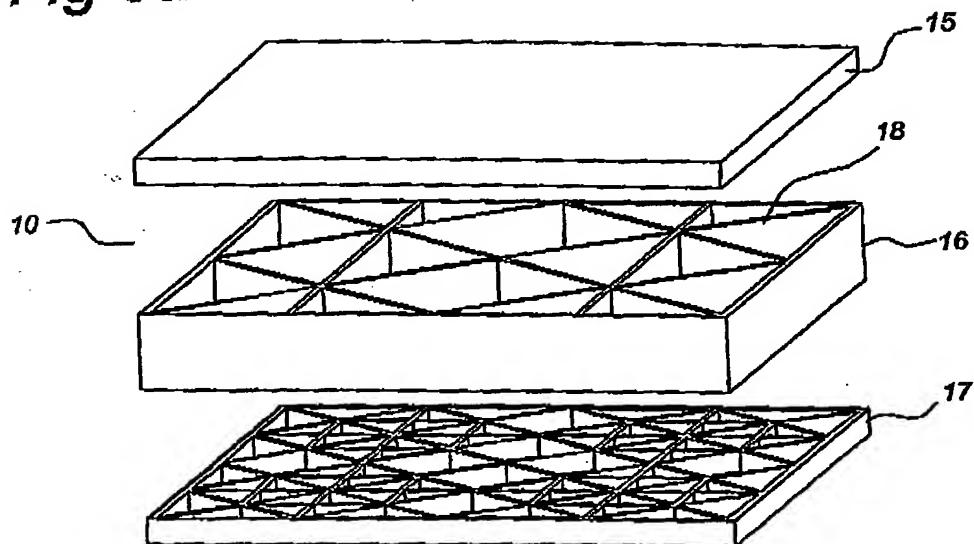
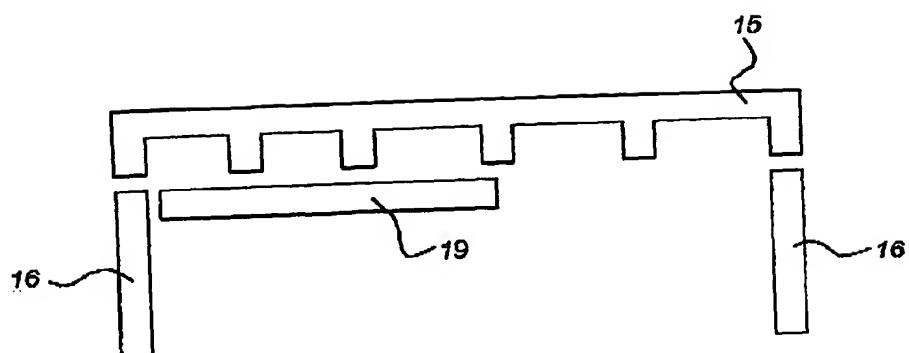
Fig 4a*Fig 4b*

Fig 5a*Fig 5b*

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